Claims

What is claimed is:

1. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:

an upper tubular support member defining a first passage;

one or more cup seals coupled to the exterior surface of the upper tubular support member for sealing an interface between the upper tubular support member and the expandable tubular member;

an upper cam assembly coupled to the upper tubular support member comprising:

a tubular base coupled to the upper tubular support member; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the tubular support member;

a lower tubular support member defining a second passage fluidicly coupled to the first passage releasably coupled to the upper tubular support member;

a lower cam assembly coupled to the lower tubular support member comprising:

a tubular base coupled to the lower tubular support member; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments; and

wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member.

2. The apparatus of claim 1, wherein the upper tubular support member comprises:

a safety collar;

a torque plate coupled to the safety collar comprising a plurality of circumferentially spaced apart meshing teeth at an end;

an upper mandrel comprising a plurality of circumferentially spaced apart meshing teeth at one end for engaging the meshing teeth of the torque plate and an external flange at another end; and

a lower mandrel coupled to the external flange of the upper mandrel comprising an external flange comprising a plurality of circumferentially spaced apart meshing teeth.

3. The apparatus of claim 2, wherein the tubular base of the upper cam assembly comprises a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the external flange of the lower mandrel.

4. The apparatus of claim 2, further comprising:

a stop nut coupled to an end of the lower mandrel for limiting the movement of the lower tubular member relative to the lower mandrel.

5. The apparatus of claim 2, further comprising:

locking dogs coupled to the lower mandrel.

6. The apparatus of claim 1, wherein the lower tubular support member comprises:

a float shoe adapter comprising a plurality of circumferentially spaced apart meshing teeth at one end, an internal flange, and a torsional coupling at another end;

a lower retaining sleeve coupled to an end of the float shoe adapter comprising an internal flange for pivotally engaging the lower expansion cone segments; and

a retaining sleeve received within the float shoe adapter releasably coupled to the upper tubular support member.

7. The apparatus of claim 6, wherein an end of the retaining sleeve abuts an end of the tubular base of the lower cam assembly.

8. The apparatus of claim 6, wherein the tubular base of the lower cam assembly comprises a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the float shoe adaptor.

9. The apparatus of claim 6, further comprising:

a float shoe releasably coupled to the torsional coupling of the float shoe adaptor; and

an expandable tubular member coupled to the float shoe and supported by and movably coupled to the upper and lower expansion cone segments.

10. The apparatus of claim 1, further comprising:

one or more shear pins coupled between the upper tubular support member and the lower tubular support member.

11. The apparatus of claim 1, further comprising:

a stop member coupled to the upper tubular support member for limiting movement of the upper tubular support member relative to the lower tubular support member.

12. The apparatus of claim 1, further comprising:

a float shoe releasably coupled to the lower tubular support member that defines a valveable passage; and

an expandable tubular member coupled to the float shoe and supported by and movably coupled to the upper and lower expansion cone segments.

13. The apparatus of claim 1, wherein each upper expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces; and

wherein each lower expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces.

14. The apparatus of claim 13, wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

15. The apparatus of claim 1, wherein each of the one or more cup seals comprise:

a sealing cup comprising

a substantially unrestricted lip for sealing engaging the expandable tubular member, and

a base portion for sealingly engaging the tubular support member,

a protecting member positioned longitudinally along the tubular support member, and

a conical bushing positioned partially between the sealing cup and the tubular support member for supporting the base portion of the sealing cup.

16. The apparatus of claim 15 further comprising a pliant backup member positioned between the protecting member and the sealing cup.

17. The apparatus of claim 16 wherein the pliant backup member is made from a material selected from the group consisting of fluropolymer, fluoroelastomer, Telflon, or PEEK.

18. The apparatus of claim 15 further comprising a restraining member surrounding the base portion of the sealing cup for restraining the sealing cup.

19. The apparatus of claim 15 wherein the protecting member is a thimble surrounding the base portion of the sealing cup.

20. The apparatus of claim 19 wherein the sealing cup further comprises an unsupported portion between the thimble and a point of engagement with the expandable tubular member, and a means for reducing the unsupported portion of the sealing cup.

21. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:

a safety collar;

a torque plate coupled to the safety collar comprising a plurality of circumferentially spaced apart meshing teeth at an end;

an upper mandrel comprising a plurality of circumferentially spaced apart meshing teeth at one end for engaging the meshing teeth of the torque plate and an external flange at another end;

a lower mandrel coupled to the external flange of the upper mandrel comprising an external flange comprising a plurality of circumferentially spaced apart meshing teeth;

a stop nut coupled to an end of the lower mandrel;

an upper retaining sleeve coupled to the lower mandrel comprising an internal flange;

one or more cup seals coupled to the upper mandrel for sealing an interface between the upper mandrel and the expandable tubular member;

an upper cam assembly coupled to the lower mandrel comprising:

a tubular base comprising a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the external flange of the lower mandrel; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper retaining sleeve;

a float shoe adapter comprising a plurality of circumferentially spaced apart meshing teeth at one end, an internal flange, and a torsional coupling at another end;

a lower retaining sleeve coupled to an end of the float shoe adapter comprising an internal flange;

a retaining sleeve received within the float shoe adapter;

one or more shear pins for releasably coupling the retaining sleeve to the stop nut;

a lower cam assembly coupled to the float shoe adapter comprising:

a tubular base comprising a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the float shoe adapter; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly;

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower retaining sleeve and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

a float shoe releasably coupled to the torsional coupling of the float shoe adaptor; and

an expandable tubular member coupled to the float shoe and supported by and movably coupled to the upper and lower expansion cone segments;

wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments;

wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member;

wherein each upper expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces;

wherein each lower expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces;

wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and

wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

22. A collapsible expansion cone assembly comprising:

an upper tubular support member comprising an internal flange;

an upper cam assembly coupled to the upper tubular support member comprising:

a tubular base coupled to the upper support member; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member;

a lower tubular support member comprising an internal flange;

one or more frangible couplings for releasably coupling the upper and lower tubular support members;

a lower cam assembly coupled to the lower tubular support member comprising:

a tubular base coupled to the lower tubular support member; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments; and

wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member.

23. The assembly of claim 22, wherein each upper expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces; and

wherein each lower expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces.

24. The assembly of claim 22, wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and

wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

25. A collapsible expansion cone assembly, comprising:

an upper tubular support member comprising an internal flange;

an upper cam assembly coupled to the upper tubular support member comprising:

a tubular base coupled to the upper support member; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member;

a lower tubular support member comprising an internal flange;

one or more frangible couplings for releasably coupling the upper and lower tubular support members;

a lower cam assembly coupled to the lower tubular support member comprising:

a tubular base coupled to the lower tubular support member; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments;

wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member;

wherein each upper expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces;

wherein each lower expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces;

AMENDED CLAIMS
[received by the International Bureau on 20 August 2004 (20.08.04);
original claims 26, 29, 40 and 42 amended; claims 44-49 added,
remaining claims unchanged (6 pages)].

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces;

wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and

wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

26. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:

a tubular support member;

a collapsible expansion cone coupled to the tubular support member;

an expandable tubular member coupled to the collapsible expansion cone;

means for displacing the collapsible expansion cone relative to the expandable tubular member using fluid pressure; and

means for collapsing the expansion cone.

27. The apparatus of claim 26, wherein the tubular support member comprises an upper tubular support member comprising an internal flange and a lower tubular support member comprising an internal flange; wherein the expansion cone comprises:

an upper cam assembly coupled to the upper tubular support member comprising:

a tubular base coupled to the upper support member; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member;

a lower cam assembly coupled to the lower tubular support member comprising:

a tubular base coupled to the lower tubular support member; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange

of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly; and wherein the apparatus further comprises:

means for releasably coupling the upper tubular support member to the lower tubular support member; and

means for limiting movement of the upper tubular support member relative to the lower tubular support member.

28. The apparatus of claim 26, further comprising:

means for pivoting the upper expansion cone segments; and

means for pivoting the lower expansion cone segments.

29. The apparatus of claim 26, further comprising:

means for pulling the collapsible expansion cone through the expandable tubular member using fluid pressure.

30. A collapsible expansion cone, comprising:

an upper cam assembly comprising:

a tubular base; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly;

a lower cam assembly comprising:

a tubular base; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly;

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

means for moving the upper cam assembly away from the lower expansion cone segments; and

means for moving the lower cam assembly away from the upper expansion cone segments.

31. The apparatus of claim 30, wherein the upper and lower expansion cone segments together define an arcuate spherical external surface.

32. The apparatus of claim 30, wherein each upper expansion cone segment comprises:
an inner portion defining an arcuate cylindrical upper surface and arcuate cylindrical lower surfaces;
an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and
an outer portion defining arcuate cylindrical upper and lower surfaces; and
wherein each lower expansion cone segment comprises:
an inner portion defining an arcuate cylindrical upper surface and arcuate cylindrical lower surfaces;
an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and
an outer portion defining arcuate cylindrical upper and lower surfaces.

33. The apparatus of claim 30, wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and
wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

34. A packer cup apparatus comprising:
a central mandrel,
a sealing cup comprising
a substantially unrestricted lip for sealing engaging a tubular member, and
a base portion for sealingly engaging the central mandrel,
a protecting member positioned longitudinally along the central mandrel,
a pliant backup member positioned between the protecting member and the sealing cup,
a conical bushing positioned partially between the sealing cup and the central mandrel for supporting the base portion of the sealing cup.

35. The apparatus of claim 34 wherein the pliant backup member is made from a material selected from the group consisting of fluropolymer, fluoroelastomer, Telflon, or PEEK.

36. The apparatus of claim 34 further comprising a restraining member surrounding the base portion of the sealing cup for restraining the sealing cup.

37. The apparatus of claim 34 wherein the protecting member is a thimble surrounding the base portion of the sealing cup.

38. The apparatus of claim 37 wherein the sealing cup further comprises an unsupported portion between the thimble and a point of engagement with the expandable tubular member, and a means for reducing the unsupported portion of the sealing cup.

39. A method of radially expanding and plastically deforming an expandable tubular member, comprising:

supporting the expandable tubular member using a tubular support member and a collapsible expansion cone;

injecting a fluidic material into the tubular support member;

sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member;

displacing the collapsible expansion cone relative to the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member;

sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member; and

collapsing the collapsible expansion cone when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member.

40. The method of claim 39, further comprising:

pulling the collapsible expansion cone through the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member.

41. The method of claim 40, wherein pulling the collapsible expansion cone through the expandable tubular member comprises:

coupling one or more cup seals to the tubular support member above the collapsible expansion cone;

pressuring the interior of the expandable tubular member below the cup seals; and

pulling the collapsible expansion cone through the expandable tubular member using the cup seals.

AMENDED SHEET (ARTICLE 19)

42. The method of claim 39, wherein the tubular support member comprises an upper tubular support member and a lower tubular support member; and wherein collapsing the collapsible expansion cone comprises displacing the upper tubular member relative to the lower tubular support member.

43. The method of claim 42, wherein the collapsible expansion cone comprises:

an upper cam assembly comprising:

a tubular base; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the upper tubular support member;

a lower cam assembly comprising:

a tubular base; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly.

44. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:

a tubular support member;

a collapsible expansion device coupled to the tubular support member;

an expandable tubular member coupled to the collapsible expansion cone;

means for displacing the collapsible expansion device relative to the expandable tubular member using fluid pressure; and

means for collapsing the expansion cone.

45. The apparatus of claim 44, further comprising:

means for pulling the collapsible expansion device through the expandable tubular member using fluid pressure.

AMENDED SHEET (ARTICLE 19)

46. A method of radially expanding and plastically deforming an expandable tubular member, comprising:

supporting the expandable tubular member using a tubular support member and a collapsible expansion device;

injecting a fluidic material into the tubular support member;

sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member;

displacing the collapsible expansion device relative to the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member;

sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member; and

collapsing the collapsible expansion device when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member.

47. The method of claim 46, further comprising:

pulling the collapsible expansion device through the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member.

48. The method of claim 47, wherein pulling the collapsible expansion device through the expandable tubular member comprises:

coupling one or more cup seals to the tubular support member above the collapsible expansion device;

pressuring the interior of the expandable tubular member below the cup seals; and

pulling the collapsible expansion device through the expandable tubular member using the cup seals.

49. The method of claim 46, wherein the tubular support member comprises an upper tubular support member and a lower tubular support member; and wherein collapsing the collapsible expansion device comprises displacing the upper tubular member relative to the lower tubular support member.